Chapter 9
Suggested Maintenance (Minimum and Optimum)

The following paragraphs list recommended maintenance practices, intervals, and evaluation processes. They are adapted from more in-depth discussions elsewhere (e.g., Borch, Smith, and Noble 1993; Howsam, Misstears, and Jones 1995; Powers 1992; Smith 1995; ADITC 1997; NGWA 1998) and project experience.

9-1 Design Aspects

A variety of design considerations can serve to prevent or slow well system deterioration, and facilitate maintenance and rehabilitation in the future. In many cases, the improvements cost little or no more than inferior designs and materials initially, and save money in life-cycle costs.

a. Improved materials. Corrosion- and deterioration-resistant materials slow the deterioration of well components and limit recurrence of preventable problems, making the success of maintenance actions more likely. EM 1110-1-4008 provides information on material compatibility. Specific to well equipment, polyvinyl chloride (PVC) casing, for example, is corrosion-resistant and suitable for most HTRW applications. Alternative metal casings are available where plastic or fiberglass casings are not suitable (Smith 1995; NGWA 1998). Notable product developments (approaching 20 years in service) include the widespread availability of all-stainless-steel and stainless-and-plastic pumps, high-quality rigid plastic pump discharge (drop) pipe with twist-on-twist-off connections, and flexible discharge hose (specifically designed for well pump use) composed of reliable, high-strength, corrosion-resistant material that permits easy pump service. Relatively smooth pump interior surfaces and corrosion resistance are showing increasing intervals between pump service events.

b. Other pump selection considerations. Pump motor and discharge-end product lines can seem to have a remarkable sameness in a competitive market. On the other hand, pumps may be marketed for "environmental duty" which may not be superior to other products for aggressive ground water pumping applications. Some considerations:

(1) Pump end material selection.

(a) A material designation of "stainless steel" includes a range of corrosion-resisting alloys. Some do well in anaerobic environments typical of high-organic-carbon water (e.g., Type 316 and better), and some do not (Type 304). The alloy should be selected to be compatible with the service environment.

(b) Welding and stamping alter the corrosion-resisting characteristics of stainless steel alloys so that the manufactured product may not match the resistance of the unaltered alloy. In some cases, a cast stainless bowl selection may be superior.

(c) While versatile, stainless steel may not suit every situation. In some high-chloride, bio-corrosive environments, only high-silicon bronze or plastics may provide suitable service life. At high temperature or high radiological activity , some plastics degrade at unacceptable rates. In addition to bowl and impeller materials, selections of bearing materials and designs are factors in selection.

(2) Pump end hydraulic efficiency. Higher efficiency pump ends are recommended. Pump impeller-bowl designs and numbers of stages should be matched to the operating head conditions.

(3) Submersible vs. lineshaft installations. In general, submersible models are more versatile but characteristically provide less wire-to-water efficiency than many lineshaft turbine models. Lineshaft installations offer the advantage of having the motor at the surface, where it is accessible, heavy motors for very large pumps are not suspended downhole, and motors are less expensive to repair. Disadvantages of lineshaft installations include:

- The need for a lineshaft and its associated bearings which require lubrication and are vulnerable to wear, especially in aggressive, biofouling water.
- The need to use steel column pipe, which is subject to rapid corrosion.
- Restricted access at the surface for drawdown measurement and other access to the well casing.
- Greater skill is needed in lineshaft pump repair, and wells must be very straight and plumb.
- Surface-mounted motors must be protected from weather and heated or cooled as needed.

(4) Achieving a balance of equipment features. As exact matches to conditions and ideals may not be possible, pump choice may be a balance of features. In general, the highest efficiency pump models should be used. Exceptions occur where service is so severe that short operating lifespans can make more expensive, tunable pumps not cost-effective to operate. In these cases (particularly where efficiency differences are minor), low-priced but serviceable pumps that can be discarded and replaced or cleaned may be the better option.

c. Computers and controllers. Automated water-level and flow information facilitates data analysis and planning. Devices exist to provide "real time" water-level and flow measurements without personnel being onsite. SCADA systems originally developed for process treatment can be adapted for well fields, permitting rapid, easy, and continuous monitoring of well and pump hydraulic performance, and even physical-chemical changes. Pump controllers help to maintain regular current flow of the proper characteristics and phase to pump motors, thereby prolonging motor life and shielding motors from line surges. All pump motors should be equipped with automatic controllers.

d. Suction flow control. One technology that has developed in recent years is the refinement of the controlled-inflow pump tailpipe referred to as a suction flow control device (SFCD). These simple devices are perforated pump intake pipes. The perforations are made in a pattern that forces flow to enter the well in a more cylindrical fashion (Nuzman 1989 and Ehrhardt and Pelzer 1992), instead of

- An upward-faced cone pattern typical of pumped screened wells in which almost all flow enters through the top 10 to 15% of the screen when the pump is above the screen.
- Preferentially at the point where the pump is located within the screen, typical of many HTRW pumping wells.

Unfortunately, practical commercial access to the best quality devices is at present still limited to Europe and the Mediterranean, and inclusion in U.S. site planning has to await commercial availability in this country.

e. Well and water system modifications to facilitate maintenance. A maintenance-friendly wellhead setup is important to minimize the difficulty of performing maintenance. Issues include meeting limits to avoid confined space designation, making the well seal secure but removable, and discharge head and instrument connections easy to detach. Table 9-1 provides recommendations for wellhead features to facilitate maintenance.

f. Wellhead chemical treatment.

(1) A hydrant should be installed between the well pitless discharge and the well house flow meter-valve assembly for discharge to waste during treatment. Several suitable self-draining hydrant styles approved for potable water distribution are available on the market (ANSI/AWWA C503 and CEGS 02510). During the well treatment process, a hose may be run from the blowoff hydrant to containment and treatment.

(2) Chemical feed pumps can be used to meter chemical mixtures into wells (CEGS 11242). The manufacturer should also be consulted about the chemical compatibility of diaphragm and housing of the liquid end. Also, the suitability of hose installed for short term, periodic service feeding pH 2 solutions should be double-checked.

Table 9-1. Design and Equipment for Wellheads to Facilitate Maintenance

Recommended Features	Feature Application
Room exists for personnel to operate and manipulate equipment around the wellhead, reasonably accessible, dry and stable wellhead area, elimination of confined-space-entry conditions.	Improves accuracy and reduces the potential for accidental injury or equipment damage or loss. Minimizes personnel needs for routine tasks; reduces time and equipment required for maintenance events.
Locks, caps, or security apparatus are corrosion- and weather-resistant	Personnel do not waste time and risk injury or equipment damage attempting to perform maintenance. Instrumentation is not easily damaged by heat, cold, or vandalism.
Water-level measurement access and flow readings are easily obtained	Personnel can perform these tasks efficiently and willingly.
Wellhead structures and fittings permit easy removal of pumps and downhole equipment.	Pumps can be removed quickly, saving money.
Piping and valving is designed to limit pressure drops, and permit convenient flow diversion and pipe maintenance.	Clogging is minimized, and maintenance flushing and pigging can be accomplished. See paragraphs 9-1f and 9-1g.
Water quality taps are accessible and protected from weather and corrosion.	Samples can be readily obtained and taps maintained.

(3) Systems have been developed to systematically redevelop with the pump in place, and designed to provide treatment chemicals to the screen where past pump-in-place designs were not effective. An example is a system in which a valved return flow pipe is installed to permit periodic or demand flushing of the well water column. These should be considered as maintenance treatment options.

g. Distribution pipeline maintenance. Distribution lines from wells may also develop deposits of iron oxides and biofilm. If oxidation and fouling in wells are kept to a minimum, lines are likely to remain relatively clean. However, line clogging is a very common problem in systems pumping contaminated ground water to treatment.

(1) If the system head shows signs of increasing, a program of pigging and flushing can be instituted. Pigging is the process of running a soft plug with a rough, abrasive outside surface through the lines to remove deposits. (The procedure is described in Deb et al. (1990)). Some system modification

will be needed to accommodate the procedure, and it is recommended that planning for this option be part of well system design. Pigging requires:

- An upstream entry point for the pig (for example at a well house).

- A means of providing water pressure to propel the pig (water pressure from a potable water system fire hydrant would suffice).

- An outlet collection point for wastewater and pig.

(2) Alternatives such as electrostatic dispersion of colloidal fouling components have also been suggested, and possibly have application.

h. Well array design recommendations. These design recommendations are detailed below.

(1) Have enough wells installed in a pumping or injection array to permit continued operation and plume control while wells are out of service (being treated or pumps replaced).

(2) Install a ring of treatment wells around pumping or injection wells subject to clogging (Section 5-4). These can greatly improve treatment success in the near-well formation by providing a way to force treatment chemicals toward the pumping well screen from the outside and also to provide more access for agitation of the near-well formation.

(3) On sites with very deep wells, options (1) and (2) may be quite expensive. In these cases, where both replacement and rehabilitation may be very expensive and difficult, designing and planning for a rigorous maintenance defense of the existing pumping wells are especially important.

9-2 Chemical Addition

a. Methods of addition. Chemicals may be introduced into wells by gravity (tremie), pumping in against water column pressure, and high-pressure jetting. A feature of each is that chemical solutions are directed to the screen region and not simply poured into the well. For maintenance treatments, simple pouring and pumping (versus jetting or pressurizing) is usually sufficient. Jetting may be used for more completely developed clogging situations. Note that both redevelopment methods and chemicals used in maintenance (as well as rehabilitation) treatments can be hazardous to personnel and possibly damaging to well structures.

b. Professionalism. Any treatment program must be initiated by professional contractors highly familiar with these treatments. Site personnel can be trained in the safe use and evaluation of the effectiveness of these methods by the contractor.

9-3 Mechanical Agitation

Chemicals introduced should be mixed through the screen column, either through surging (see Section 9-5) or recirculation pumping. As it is mixed and pumped in, and later during development, the solution should be checked and adjusted to maintain pH <2. Current research under way at the Canadian Federal Government's Praire Farm Rehabilitation Administration's geotechnical laboratory suggests that most chemicals should have a maximum in-well contact time of less than 10 hr where clay swelling is a possibility.

9-4 Chemical Recovery

Chemical solutions containing biofilm, metal oxides, and other solid debris must be removed from the well column. It is essential to note that neutralization should never be conducted in the well column itself, because

- Clogging material will drop out of suspension or solution.
- Explosive effervescence is possible when caustic solutions are introduced into solids-laden acid solutions.

a. Containment. Containment and treatment such as neutralization are then necessary before release into the environment. Options include:

(1) Pump into holding tanks. Development slurries are typically best pumped to pretreatment tanks for settling and acid neutralization. Such tanks should be sufficiently large to hold three to six times the borehole volume so that development (Section 9-5) does not have to stop. Other options include neutralization "on the fly" in smaller tanks using a calculated feed rate of neutralizing chemical solution.

(2) Divert to existing lagoons. On occasion, slurries may be diverted to surface containment and permitted to lose acid or oxidant power. Solids may settle in place.

(3) Divert to treatment plant. Typically on HTRW remediation sites, water treatment is available, and development slurries must pass through them prior to release. Typically pretreatment is necessary. The tolerances and requirements of the treatment process should be known and not exceeded.

b. Regulatory aspects. Environmental regulations and standards that apply to such impoundments apply. Project agreements with regulators and local regulations may need to be checked before discharging to existing treatment plants or lagoons if they were not originally intended to accept such waste. Ultimately solids must go to secure disposal per regulatory requirement.

9-5 Well Development

Practically all methods of drilling cause compaction of unconsolidated materials of variable thickness in an annulus around a drill hole. In addition, fines are driven into the wall of the hole, drilling mud invasion may occur to a greater or less extent, and a mud cake (if used) may form on the wall of the hole. These effects are well described in standard well construction references such as ADITC (1997) and Driscoll (1986).

a. Defining well development and redevelopment. Well development is the final well construction step that

- Removes formation damage caused by the borehole drilling process.
- Establishes the optimal hydraulic contact possible between the well and the aquifer formation supplying fluids to (or accepting fluids from) the well.

Redevelopment is the process of using development methods to remove accumulating clogging material from around an installed well.

b. Well development and redevelopment effects. The importance of proper initial well development and redevelopment in well maintenance is difficult to emphasize enough. Proper well development breaks down the compacted borehole wall, liquefies gelled mud, and moves both mud and formation fines into the well, from which they are removed by bailing or pumping. This action creates a more permeable and stable zone about the screen or intake bore. The stabilization of the formation adjacent to the well intake that is achieved by development can practically eliminate sand pumping, and contributes to a more efficient well, longer well life, and reduced operation and maintenance costs. EM 1110-2-1914 and TM 5-813-1 provide general guidance on well development. Numerous detailed references on development methods are available, including ADITC (1997), Driscoll (1986), and Roscoe Moss Company (1992). Borch, Smith, and Noble (1993) provide information and guidance from a redevelopment perspective. NGWA (1998) provides specific pumping well methods description and guidance.

c. Well development and redevelopment methods.

(1) Overpumping. The development process consists of continuous or intermittent pumping at pumping rates up to 1-1/2 times the design capacity. Overpumping lacks the necessary in-and-out action of optimal development action but can be conducted with available well pumps.

(2) Surging and bailing (utilizing surge block). The development process is carried out by surging and bailing the well. The surging is done by a single or double solid (or valved) surge block with development water and sediment removed typically by airlift pumping. Surging should be conducted with tools capable of a 0.3- to 0.6-m/sec (1- to 2-ft/sec). stroke and capable of working the screen in 0.6- to 1.5-m (2- to 5-ft) sections, concentrating on known trouble spots. One variation is swabbing (e.g., Roscoe Moss Co., 1992).

(3) Surging and pumping. Where there is insufficient submergence for airlift pumping to work properly, development can proceed using surging and pumping with a well pump. Pumping is conducted through the surge block which incorporates a piece of the suction pipe in the fabrication of the block, at rates up to one half of the design capacity. Upon completion of the development work, the well is cleaned to the bottom. A variation of surging and pumping and overpumping, especially useful in tight wells, employs a well pump moved up and down with a reversible pump puller. Pumps especially equipped for this purpose with attached surge block collar, etc., are available. Care must be taken to ensure that air does not enter the formation, but is only used to move fluid, which carries the kinetic development force (see paragraph 9-5e).

(4) Hydraulic jetting. Development is accomplished by simultaneous high velocity, horizontal jetting and pumping. The outside diameter of the jetting tool must be 1 in. (about 25 mm) less in diameter than the screen inside diameter. The minimum exit velocity of the jetting fluid at the jet nozzle should be 150 ft/sec (45 m/sec). The tool is rotated at a speed less than 1 rpm and positioned at one level for not less than 2 min and then moved to the next level, which is no more than 6 in. (150 mm) vertically from the preceding jetting level. Pumping from the well should be at a rate of 5 to 15% more than the rate at which water is introduced through the jetting tool. Water to be used for jetting must contain less than 1 ppm suspended solids.

(5) Air development. Development is conducted:

- Using a single pipe air pumping system either using the casing or the bore hole itself as the eductor line (casing open) or with the casing closed to the atmosphere.
- With a dual-line air system employing an air introducing pipe and an air and water eductor line.

(a) Sizing. Compressors, airlines, hoses, fittings, etc., should be of adequate size to pump the well by the airlift method at l-l/2 to 2 times the design capacity of the well. Each case is specific in terms of depth, submergence, well diameter, and screen hydraulic conductivity. For wells less than 300 ft (91.4 m) in depth, with 60% submergence possible, approximately 0.75 cfm of air compressor capacity is needed per gpm (0.133 cfm) (~5.6 m^3/sec of air per 1 m^3/sec water) of anticipated pumping rate (Driscoll 1986, Fig. 15.12). In practice, a 375-cfm compressor developing 100 psi can usually pump 400 to 500 gpm (approximately 44 to 67 cfm or 1.25 to 2.0 m^3/sec) of water with proper airline submergence.

(b) Development process. The first goal is to establish a piston effect (surging) and not to conduct airlift pumping. In surging, sufficient air is fed to raise the water level as high as possible, then released to let it drop. Airlift pumping is then used to pump the well periodically to remove sediment from the screen or borehole. When the well yields clear, debris-free water, the airline is lowered to a point below the bottom of the eductor line and air introduced until the water between the eductor pipe and the casing is raised to the surface. At this time the airline is raised back up into the eductor line causing the water to be pumped from the well through the eductor line. The procedure of alternating the relative positions of the air and eductor line is repeated until the water yielded by the well remains clear when the well is surged and backwashed by this technique.

(6) Combination tools and methods: The better features of several tools and methods can be combined. For example, combination surging and jetting tools are used to surge while jetting in acid.

d. Care in performing development. To avoid applying forces on the casing, screen, and grout that are beyond their capacity for resistance, care and attention to detail are required in development and redevelopment. Sufficient force, efficiently supplied, is needed to set formation particles in motion and to sheer off encrustation. However, this does not have to be violent force that damages the well. For example, causing an excessive difference in hydrologic pressure between the outside and inside of a casing may result in casing distortion. Sharp shock loading or unloading of some well screens may cause distortion or collapse.

(1) Development typically should proceed in 2.74- to 4.57-m (3- to 5-ft) segments.

(2) Tools should not impact sharply against casing joints or screen rods.

(3) In air development, especially, there is a tendency to “overdo it.” Sufficient air flow volume (cfm) should be available (paragraph 9-5d(5)(a)) to mobilize the water in the well and the near-well formation, but being careful to not disturb the filter pack. Exceeding a 10:1 air-water volume ratio can actually reduce airlift pumping flow rates because the well is impeded by excessive air volume.

9-6 Maintenance Monitoring Well Deterioration and Redevelopment Evaluation

a. Evaluation in the PM plan. Including recommendations, processes, and checklists for methods to evaluate well performance, its deterioration, and repair and treatment results in the well system PM plan permits evaluation of treatment effectiveness, the need for additional actions, or changes in subsequent treatment. An overview of maintenance monitoring schedule and parameter recommendations is provided in Sections 5-2 and 5-3.

b. PM evaluation instrumentation recommendations. The following are some specific instrument recommendations for maintenance monitoring:

(1) Physical-chemical monitoring for maintenance water quality testing. Electronic colorimetric or spectrophotometric instruments and electronic pH-mV, temperature, and conductivity meters are

sufficient for PM monitoring with proper calibration (CEGS 13405). If there is an established maintenance and calibration schedule for all instruments, accuracy is not sacrificed using onsite, commercially available instrumentation, and the greater frequency of analysis possible economically provides more data points to plot trends.

(2) Biofouling microbial component.

(a) Sampling. Pumped grab methods in time-series for BART and turbid sample analysis by microscopy and biofilm collection on surfaces (sidearm for outflow from wells to collect samples of biofouling indicative of that occurring in wells).

(b) Analysis. Light microscopy and BART methods (Section 2-8), biofilm mineralogical analysis (X-ray diffraction for mineralogy and elemental speciation to establish fouling mineral predominant components).

(c) Recommendation. A combination of time-series pumped sampling and BART analysis and microscopy for filamentous iron and sulfur bacteria and FeIII-oxide minerals provides a good profile of biofouling conditions. Routine monitoring can be limited to specific BART analyses selected to best gauge change and periodic sampling of biofouling solids to gauge changes in type and structure (Sections 5-2 and 5-3 provide a schedule). A one-time mineralogical (XRD) and elemental analysis of solids is useful to refine preventive maintenance chemical feed choices.

(d) Alternative. Particle counting and turbidity (both of which can be automated) can replace biofouling sampling in systems with known biofouling characteristics.

(3) Sand content testing. Sand content may be determined by sampling with a Rossum Valve sampler (Roscoe Moss Company 1992)

(a) At strategic intervals during well development.

(b) Averaging the results of five samples collected at incremental times during a pumping test. NGWA (1998) provides specific recommendations. A limit of 5 ppm is achievable and optimal criterion for well redevelopment completeness.

(c) Hydraulic monitoring using methods as described (Section 2-1).

c. Flow meter and other sensor maintenance. To ensure their usefulness in maintenance monitoring, flow meters, and other sensors must be maintained. An open pipe insert type or nonintrusive ultrasonic flow meter should be used to limit the effects of encrustation. Units that can be readily removed should be specified and installed. If used, venturi flow meters (vulnerable to clogging) and sensors (vulnerable to coating and fouling) should be periodically examined and cleaned as needed. Manual cleaning using a mild acid detergent and rinse should suffice.